Smart Material Actuated Servo Hydraulics (SMASH)

DARPA Compact Hybrid Actuator Program (CHAP) Kickoff Meeting

Baltimore, MD
28 June 2000

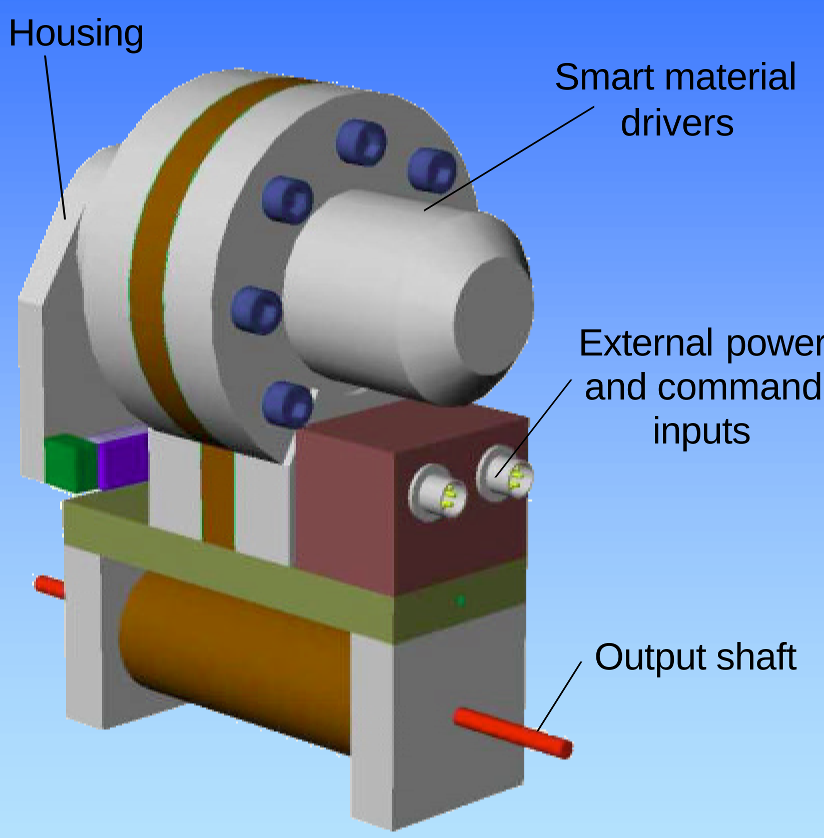
Presented by:

Eric H. Anderson

CSA Engineering Inc.

Smart Material Actuated Servo Hydraulics

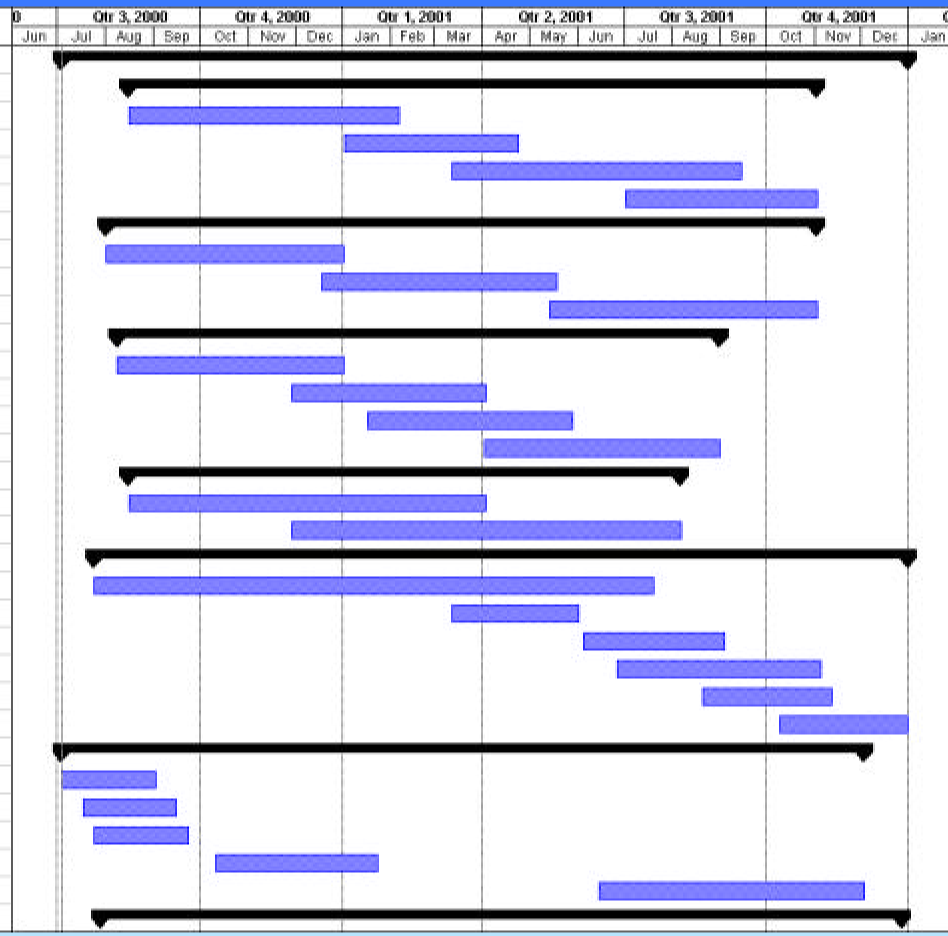
- 18-month effort beginning June 30
- Integrated device to replace ballscrews, DC motors and all-hydraulic actuators
- High frequency piezoelectric actuators with fast acting valves
- Closed fluid system and direct pressurization
- Moderate frequency (DC - 50 Hz) hydraulic output device
- High efficiency power conversion
- Major emphasis on end-to-end efficiency
- Phase 1 will result in fully-functional prototype device



SMASH Concept

Program Schedule

ID	Task Name
1	**1. Phase I: Proof of Concept**
2	**1.1 Mechanical/Smart Materials**
3	1.1.1 Conceptual design
4	1.1.2 Component hardware development
5	1.1.3 Subsystem tests
6	1.1.4 Design iteration
7	**1.2 Fluids and Hydraulics**
8	1.2.1 Conceptual design
9	1.2.2 Detailed design
10	1.2.3 Predict performance limits
11	**1.3 Power Electronics**
12	1.3.1 Drive system design
13	1.3.2 Prototype development & test
14	1.3.3 Design iteration
15	1.3.4 Hardware development & test
16	**1.4 Control/Sensing/Electronics**
17	1.4.1 Conceptual design
18	1.4.2 Prototype development and tests
19	**1.5 Device/System Integration**
20	1.5.1 Develop system model
21	1.5.2 System interface study
22	1.5.3 Electronic integration
23	1.5.4 Mechanical integration
24	1.5.5 Electromechanical integration
25	1.5.6 Device integration & test
26	**1.6 Requirement /Applications Definitions**
27	1.6.1 Gather applications requirements
28	1.6.2 Assemble device requirements
29	1.6.3 Subsystem and component requirements
30	1.6.5 Test existing devices
31	1.6.4 Revisit apps requirements
32	**1.7 Administration**



The SMASH Team

CSA Engineering

E. Anderson, P. Atkins, M. Evert, P. Flannery, J. Lindler

Device design
Smart materials
Valves
Integration

Control
Electronics
Hardware
Tests

Rhombus

M. Regelbrugge, B. Hurlbert

Mechanical design
Smart materials
Device design
Integration

Univ. of Maryland

M. Lewis, N. Wereley, I. Chopra

Fluids analysis and design
Smart materials
Modeling
Valves and control

Trisys

J. Fumo, M. Jessen

Power electronics
Microcontroller
Networking
Packaging

UTRC/Hamilton Sundstrand

F. Sun

Requirements
Applications
Testing
End users

Warner Precision

R. Warner

Power electronics
Microcontroller

CSA Engineering, Inc. UNIVERSITY OF MARYLAND RHOMBUS CONSULTANTS GROUP United Technologies Research Center Hamilton Sundstrand TRISYS

Summary of Responsibilities

- Expect subcontracts to be issued by July 10
- CSA has all final hardware-related responsibilities
- Rhombus currently shares Mountain View facilities with CSA
- Trisys and Warner have collaborated with CSA on multiple projects (3 others ongoing)
- Univ. of Maryland students will spend time at CSA
- Work complements other UTRC and Hamilton Sundstrand developments

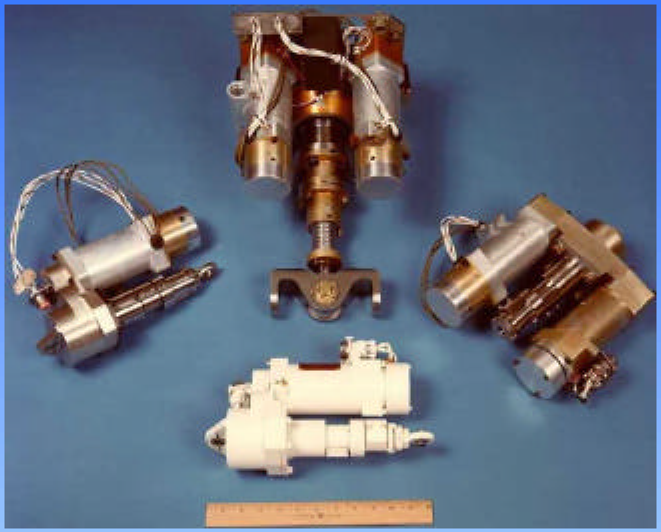
	Task	CSA	Rhombus	Trisys	UMd	UTRC/HS	Warner
1.1	Mechanical and smart materials	X	O		O		
1.2	Fluids and hydraulics	O	O		X		
1.3	Power electronics	O		X	O		O
1.4	Control/sensing electronics	X		O	O		O
1.5	System model/integration	X	O		O	O	
1.6	Requirements / Apps. Definition	X	O			O	
1.7	Administration	X					

Anticipated Accomplishments

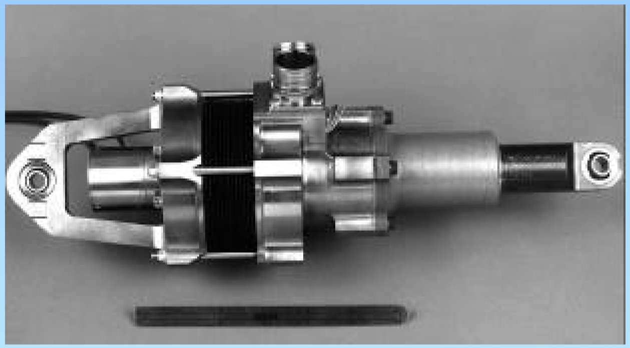
- A working prototype with performance matching identified application requirements
- Requirements for practical devices rather than research-only components
- Tight integration between electrical, mechanical, and fluid portions of the devices
- Smart device with embedded control
- Demonstration of a high speed valve with other applications in flow control

Anticipated Use of the Technology

- **Applications development is a focus of effort early and late in the 18-month Phase 1**
- **Opportunities for future use**
  - **Actuation of flight control surfaces**
  - **Replacement of ballscrew actuators**
  - **Replacement of hydraulic devices requiring distributed high pressure fluids**
  - **Specialty motion control systems**
- **Additional applications for fast-acting valves**
- **Hamilton Sundstrand is a leading actuator supplier for aerospace systems**



Current actuators



Key Concepts and Technologies

- **Smart materials**
  - Exploit high energy densities
  - High stiffnesses for high pressure operation
- **Frequency separation**
  - Integrate high frequency output from smart materials to produce useful mechanical work at lower frequency
- **Resonance**
  - Exploit dynamic amplification to minimize parasitic power
- **Impedance matching**
  - Maximize fluidic transfer of power
- **High speed valves**
  - Achieve low losses at maximum flow rates
- **Advanced fluids modeling**
  - Optimize flow path configuration accounting for non-idealities
- **Embedded control**
  - Maximize authority over local device operation
  - Minimize complexity of external interfaces

Challenges

- **Design**
  - Quantification of non-ideal fluid effects
  - Efficient physical integration of smart material elements (volume, mass, compliance)
  - Electrical subsystem that is compact, power efficient, and well integrated with the smart matertials
  - Will require a flexible prototype configuration that allows design evolution
- **Achieving required performance**
  - Operation at high pressure
  - Control of high flow rate behavior of fluids
  - High end-to-end device efficiency
- **Applicability**
  - Identification of appropriate operational requirements
  - Subsystem architecture: multiple devices vs. single (size and cost)
  - Conformance to standard interfaces

Milestones

Milestone	Date	Expected Result
Visit Hamilton Sundstrand	1 MAC	Meeting to coordinate applications effort
Kickoff meeting	1 MAC	Brings together team and brief sponsors
Publish Requirements Document	3 MAC	Set requirements until late in Phase 1
Complete testing of existing devices	6 MAC	Establishes bases for comparison of new devices
Conceptual designs complete	7 MAC	System model updated and performance predicted
Design review	9 MAC	Sponsor program review of direction and detailed design
Component tests complete	12 MAC	Performance deficiencies identified; motion amplifier and valves functioning well; prepare for integration
Applications review	13 MAC	Compare device capabilities with present needs
Final review	16 MAC	Sponsor review – device capabilites vs. applications needs
Integrated device tests complete	17 MAC	Performance and secondary limits understood